DETERMINATION OF SOIL MOISTURE CONTENT AND DENSITY USING ELECTRICAL RESISTIVITY VALUES

by

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LIST OF SYMBOLS

A	Cross section area
A(n)	Sampling point an
a	Electrode spacing
B(n)	Sampling point bn
C	Coefficient factor
C(n)	Sampling point cn
C1	Current electrode 1
C2	Current electrode 2
cm	Centimeter
D_{10}	Maximum size of the smallest 10 percent of the sample
D_{30}	Maximum size of the smallest 30 percent of the sample
D_{60}	Maximum size of the smallest 30 percent of the sample
d	Particle size
e	Void ratio
ex	Exponential
f_s	Sleeve friction
Gs	Specific gravity
g	Gram
Hz	Hertz
hr	Hour
I	Current flow
K_v	Vertical hydraulic conductivity
k	Kilo
L	Length

ln	Natural logarithm
M	Mega
MP	Mackintosh value
MC	Moisture content
m	Meter
ml	Milliliter
mm	Millimeter
N	North
(N)	Standard penetration test value
na	Distance between a current electrode to nearest potential electrode
P	Compressional wave
P1	Potential electrode 1
P2	Potential electrode 2
R	Electrical resistance of object or sample
R^2	Coefficient of determination
R_f	Friction ratio
r	Correlation coefficient
S	Shear wave
Sr	Degree of saturation
s	Second
V	Potential difference across object
V_p	P-wave velocity
Vs	S-wave velocity
w	Water content and moisture content
ρ_a	Apparent resistivity

σ_a	Apparent bulk conductivities
ρ_{Bulk}	Bulk density
q_t	Cone resistance
°	Degree
ρ_d	Dry density
ρ_w	Density of water
σ	Electrical conductivity
ρ	Electrical resistivity
∞	Infinity
<	Less than
α	Linearly proportional
>	More than
μ	Micron
μm	Micrometer
Ω	Ohm
%	Percentage
π	Pi
η	Porosity
θ	Volumetric water content

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing Materials
BS	British Standard
CC	Coefficient of Curvature
CPT	Cone Penetration Test
CQA	Construction Quality Assurance
CST	Constant Separation Traversing
CWI	Chemical Weathering Index
DC	Direct Current
DCPT	Dynamic Cone Penetration Test
EC	Electrical Conductivity
EDG	Electrical Density Gauge
EDX	Energy Dispersive X-Ray Spectroscopy
EM	Electromagnetic
ER	Electrical Resistivity
ERCP	Electrical Resistivity Cone Probe
ERI	Electrical Resistivity Imaging
ERM	Electrical Resistivity Method
ERT	Electrical Resistivity Tomography
ERV	Electrical Resistivity Value
FVRP	Field Velocity Resistivity Probe
GPR	Ground Penetrating Radar
KED	Kriging with External Drift
LL	Liquid Limit

LME	Linear Mixed Effect Model
MEMS	Micro Electro Mechanical Systems
MI	Intermediate Plasticity
MIP	Mercury Porosimetry
MSW	Municipal Solid Waste
PAW	Plant Available Water
pH	Potential of Hydrogen
PI	Plasticity Index
PL	Plastic Limit
POSD	Pores-Size Distribution
PPT	Pressure Plate Test
PSD	Particle Size Distribution
RCPT	Resistivity Cone Penetrometer
RMSE	Root Mean Square Error
SAS	Signal Averaging System
SCPTù	Seismic Piezocone Test
SM	Silty SAND
SDMTà	Seismic Flat Dilatometer
SMP	Soil Minipenetrometer
SP	Poorly Graded SAND
SPI	Special Property Index
SPSS	Statistical Package for the Social Sciences
SPT	Standard Penetration Test
SR	Seismic Refraction
SRT	Seismic Refraction Tomography

SWC	Shallow Soil Water Content
SWM	Surface Wave Method
SWV	Soil Volume Wetness
TDR	Time Domain Reflectometry
UC	Coefficient of Uniformity
UKM	Universiti Kebangsaan Malaysia
USCS	Unified Soil Classification System
VES	Vertical Electrical Sounding
VLF	Very Low Frequency
XRF	X-Ray Fluorescence
XRD	X-Ray Diffractometry
1-D	One-Dimensional
2-D	Two-Dimensional
3-D	Three-Dimensional

PENENTUAN KANDUNGAN LEMBAPAN DAN KETUMPATAN TANAH MENGGUNAKAN NILAI KEBERINTANGAN ELEKTRIK

ABSTRAK

Ciri geoteknik merupakan elemen penting dalam kerja-kerja rekabentuk dan pembinaan kejuruteraan awam. Pada masa lalu, ciri geoteknik diperolehi menggunakan teknik penyiasatan tapak konvensional melalui penggerudian dan pengorekan. Kaedah tersebut mempunyai beberapa batasan dari segi kos, masa dan liputan data. Maka kajian ini mewujudkan penentuan ciri geoteknik asas (kandungan lembapan dan ketumpatan) menggunakan korelasi data geofizik terutamanya nilai keberintangan elektrik. Kajian ini dijalankan pada tanah pasir dan pasir berkelodak dengan tahap ketumpatan yang berbeza melalui ujikaji makmal, model fizikal lapangan dan lapangan. Sampel tanah diuji di dalam makmal untuk pencirian geoteknik dan ujian keberintangan kotak tanah masing-masing berpandukan BS 1377 (1990) dan AASHTO (T-288-91). Dua model fizikal lapangan homogen pasir dan pasir berkelodak diuji menggunakan keberintangan elektrik dan pengelasan tanah. Pengesahan keputusan dibuat melalui ujikaji lapangan di Kuala Kangsar (pasir) dan Lenggong (pasir berkelodak). Analisis data dibuat menggunakan kaedah statistik dan perisian keberintangan komersial iaitu Statistical Package for the Social Sciences (SPSS), Microsoft excel dan RES2DINV. Ujikaji makmal mendapati bahawa perkaitan antara nilai keberintangan elektrik tanah dengan kandungan lembapan dan ketumpatan adalah pada korelasi sederhana hingga sangat kuat (r = -0.405 – 0.949). Satu siri nilai keberintangan elektrik tanah telah dihasilkan, justeru membolehkan penentuan cirri asas geoteknik tanah menggunakan persamaan statistik yang dihasilkan. Ciri asas geoteknik lapangan terutamanya kandungan lembapan dan

ketumpatan boleh diperolehi menggunakan persamaan statistik dengan menggunakan faktor pekali (C) yang dihasilkan daripada ujikaji model fizikal lapangan. Didapati nilai keberintangan elektrik tanah adalah berbeza dalam keadaan longgar (L) dan tumpat (D) dengan pekali penentuan, R^2 kandungan lembapan dan ketumpatan diperolehi pada nilai 0.7530 – 0.9706 dan boleh digunakan untuk anggaran melalui penggunaan faktor pekali (C) menggunakan persamaan berikut: $MC_{(L)} = 591.61\rho^{-0.557}$, $MC_{(D)} = 723.64\rho^{-0.723}$ dan $\rho_{bulk(L)} = 5.3011\rho^{-0.193}$, $\rho_{bulk(D)} = 3.3351\rho^{-0.109}$ untuk pasir dan $MC_{(L)} = 186.81\rho^{-0.265}$, $MC_{(D)} = 259.01\rho^{-0.373}$, $\rho_{bulk(L)} = 0.376\ln(\rho) + 4.3043$ dan $\rho_{bulk(D)} = 4.591\rho^{-0.138}$ untuk pasir berkelodak. Pengesahan keputusan di Kuala Kangsar dan Lenggong mendapati bahawa teknik ini boleh diguna pakai dalam menentukan kandungan lembapan dan ketumpatan tanah lapangan yang efisyen kerana pantas, ekonomi, sebaran data yang luas serta bersifat lestari dengan alam sekitar.

DETERMINATION OF SOIL MOISTURE CONTENT AND DENSITY USING ELECTRICAL RESISTIVITY VALUES

ABSTRACT

Geotechnical properties are crucial element in design and construction of civil engineering projects. In the past, geotechnical properties were determined using conventional site investigation technique based on drilling and excavation method. The techniques experienced several limitations due to cost, time and data coverage. Hence, this study established basic geotechnical properties determination (moisture content and density) using correlation of geophysical data, particularly electrical resistivity values. This study was performed on SAND and Silty SAND soil with different degree of denseness via laboratory, miniature model and field testes. The soil samples were tested in laboratory for geotechnical characterization and soil box resistivity test according to BS 1377 (1990) and AASHTO (T-288-91) respectively. Two physical field models of homogeneous SAND and silty SAND were tested using electrical resistivity and geotechnical classification. Results validations were performed via field test at Kuala Kangsar (SAND) and Lenggong (Silty SAND) sites. Data analyses were performed using statistical method and commercialize resistivity software via Statistical Package for the Social Sciences (SPSS) software, Microsoft excel and RES2DINV software. Laboratory tests identified that relationship between soil electrical resistivity value with moisture content and density were moderate to very strong correlation (r = -0.405 – 0.949). A series of soil electrical resistivity value has been produced, thus allow determining moisture content and density of soil using statistical equation developed. Field basic geotechnical properties particularly

on soil moisture content and density were able to determine using established statistical equation by applying coefficient factor (C) developed from miniature model test. It was apparent that the soil resistivity value was different under loose (L) and dense (D) conditions with moisture content (MC) and density (ρ_{bulk}) coefficient of determination, R^2 being established at 0.7530 – 0.9706 and applicable for prediction via applying coefficient factor (C) using the equation as follows: $MC_{(L)} = 591.61\rho^{-0.557}$, $MC_{(D)} = 723.64\rho^{-0.723}$ and $\rho_{bulk(L)} = 5.3011\rho^{-0.193}$, $\rho_{bulk(D)} = 3.3351\rho^{-0.109}$ for SAND and $MC_{(L)} = 186.81\rho^{-0.265}$, $MC_{(D)} = 259.01\rho^{-0.373}$, $\rho_{bulk(L)} = 0.376\ln(\rho) + 4.3043$ and $\rho_{bulk(D)} = 4.591\rho^{-0.138}$ for Silty SAND. Result verification at Kuala Kangsar and Lenggong sites found that this technique was applicable in determination of field moisture content and density efficiently due to fast, economic, large data coverage and sustainable to our environment.

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